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THE PROMISE OF PASSIVE DEFENSES

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INTRODUCTION

Tactical ballistic missiles (TBMs) have distinctive strengths as offensive, conventional weapons: they strike speedily and, in the absence of defenses, with assurance. But current versions also have distinctive weaknesses: they are not precision, "smart" weapons, nor are they cheap. Passive defenses use the weaknesses to mitigate the strengths.

Since TBMs are likely to remain an expensive method of delivering ordnance, their use will probably be restricted to targets where their fast, assured arrival would yield a high payoff. Targets for which fast arrival is less important can be more efficiently handled by slower weapons, either aircraft or cruise missiles. Thus, only for the time-critical targets is a defense against TBMs essential, whether active or passive.

For this restricted set of targets, passive defenses hold great promise. Combinations of hardening, redundancy, dispersal, and mobility can significantly reduce the damage from such TBMs, as well as mitigate the effects of other attacks. For the capabilities imputed to Soviet TBMs in the 1990s, passive defenses may be able effectively to counter conventional TBM attacks.

[1]This paper was prepared for inclusion in a book to be edited by Senator Dan Quayle entitled, *Extended Air Defense: A Plan for Action*. The views expressed in this paper are the authors' own, and are not necessarily shared by RAND or its research sponsors.

THE CAPABILITIES OF SOVIET TACTICAL BALLISTIC MISSILES

In order to understand the role of passive defenses, we must describe the properties of Soviet TBMs, starting with the overall dimensions of the threat and then concentrating on guidance and munitions.

The new Soviet missiles threatening NATO vary widely in characteristics. In order of increasing range, they are the SS-21, the SS-23, and the SS-12 Mod 2, which was earlier referred to as the SS-22. These missiles are replacements for older systems designed to support ground forces at levels from divisions through armies to fronts, respectively. Consequently, their effective ranges vary from a minimum of a few tens of kilometers for the SS-21 to 900 kilometers for the SS-12 Mod 2. This same spread in ranges is similar to the western TBM armory--moving from the U.S. Lance or French Pluton, past the U.S. Pershing Ib or French Hades, not quite to the U.S. Pershing II.

The flight times of these missiles vary with the range, but remain short compared to aircraft flight times or to intercontinental missile flight times. They range from several minutes to perhaps 15 minutes for the SS-12. The warning time for such attacks would be shorter still.

The numbers of the new Soviet systems can be estimated from the numbers of the predecessor systems--the various Frog rockets, the SS-1c and older Scud missiles, and the SS-12, respectively. In the central European theater, this would imply that roughly 500 SS-21, 400 SS-23, and 60 SS-12 Mod 2 launchers could be expected by the 1990s if all Warsaw Pact launchers were converted. Reloads may exist for these launchers, but they wouldn't change the most important aspect of the threat posed by TBMs: the quickness and hence surprise of a TBM attack--something most directly associated with the initial salvo. And, the salvo is limited to the number of launchers. Estimates of future forces are always uncertain, and we should not rely on their precision. They should, however, approximate the numbers NATO will face.

Such missiles are neither small nor cheap, which explains their limited number. The following table, drawn from *Soviet Military Power, Defense Marketing Services*, and the *World Weapon Database*, estimates the size and weight of the existing Soviet missiles, as well as some western counterparts. The unit acquisition costs, in 1985 U.S. dollars, are included for some western systems, but these numbers should be viewed as rough. The costs are taken from diverse original sources, so there is no assured consistency in accounting.

All of these systems have the principal mission of delivering nuclear warheads. Because of the enormous power of a nuclear weapon and the lack of nuclear-hardened tactical targets, the limited payload weight creates little constraint on their use. Moreover, the same considerations offer little inducement to obtain accuracies better than a few hundred meters, particularly in view of the costs usually associated with improvements. Western, and perhaps Soviet, desires to limit collateral damage, in the event the weapons were used, do provide some inducement for improvement. Nonetheless, the only western system credited with greatly improved accuracy, the Pershing II, originally developed that accuracy not to limit collateral damage, but to use either a conventionally armed, airfield-attack warhead or an earth-penetrating, nuclear warhead. Both variants were never deployed.

Table 1

CHARACTERISTICS OF SELECTED MISSILES

Missile	Maximum Range [km]	Payload [kg]	Unit Procurment Cost [FY85$]
SS-21	120	>500	--
SS-23	500	>860	--
SS-12 Mod 2	900	>860?	--
Pluto	120	500	-
Hades	350	>500?	2.700M
Lance	112	450	.500M
Pershing Ia	740	--	3.400M
Pershing II	1800	--	4.700M

GUIDANCE

The possibility of a Soviet improvement in accuracy comparable to that of new western systems raises the possibility of a conventionally armed option for their missiles. This has fueled some of the current interest in defense against tactical ballistic missiles in Europe. In principle, such accuracy could be gained via several methods: improved inertial systems, in-flight updates from a satellite positioning system such as the U.S. Global Positioning System or the Soviet GLONASS, terminal sensors that view the target region and generate correction, or a terminally guided submunition seeking an imprecisely located target. We consider each possibility in turn.

An *inertial system* capable of these accuracies seems technically possible, if costly. It would require a prelaunch "warmup," the use of presurveyed launch sites, and the location of the target in the proper coordinate system of the missile. Such systems were rejected by the United States for the Pershing II because of the associated vulnerabilities, but the Soviets might disagree, especially since an inertially guided missile is autonomous in flight and thus not susceptible to external influence, such as jamming.

A *system relying on satellites* for guidance always risks the denial of those satellites by the enemy. The satellites could be jammed so that their signals were unusable, or even destroyed. Whether such satellites would be targets in a European war is an undecidable issue. Certainly, attacks on them would be tempting if the Soviets relied on them heavily. At the very least, such satellites would be available before hostilities begin, and would probably be available for an initial TBM strike.

Technically, systems relying on satellite updates could easily achieve the accuracies posited. Moreover, they require neither a presurveyed launch site, nor a map of the target area. They do require that the target be located in the coordinates of the satellite system. For fixed targets, this is almost trivial, as it can be done long before the start of the war. For mobile targets, which could require continuous location updates, the determination becomes more challenging, but still possible given sufficient computing power and a surveillance system that knows its position in the coordinates of the satellite.

A *terminal sensor* that matches the surroundings of the target to an image stored on the missile was the technology chosen by the United States for the Pershing II. That system uses a radar to image the terrain, although other technologies could be applied. For any sensor type, a map of the surroundings must be prepared for each target. If the sensor were sensitive to changes in the surroundings, for example, a visible light sensor noticing the seasonal loss of foliage, the map would need information for the appropriate times. Independent of sensor, a mobile target must be located relative to the map. Technically, that location is a different and easier process than location for an inertial system, but the needed accuracy is still high.

Each of these guidance techniques has strengths and weaknesses, but more importantly, different vulnerabilities a defender might exploit. While a terrain-matching, radar sensor might be confused by decoy radar reflector arrays or jammers, those same decoys and jammers wouldn't affect a terrain-matching, infrared sensor, much less an inertial guidance system. In general, until a jamming system reaches levels where it destroys guidance electronics independent of sensor or guidance technique, the jamming relies on *knowledge of the* details of the guidance system. For simplistic jamming, such as broad-band noise interfering with a sensor, the defense only needs to know that such a sensor is being used and the frequency band. Unfortunately, such non-subtle techniques tend to be defeated by clever design. More sophisticated jamming can confuse any design, but needs detailed knowledge of it. That is difficult to obtain, and more difficult still to trust. If accurate TBMs must be countered, NATO can not count on knowing now what guidance technique the Soviets will use when so many possibilities are open.

Of course, if simple, cheap, radar decoys appear to deceive Soviet TBMs, there would be little penalty in deploying them. They might also serve to confuse any attacking aircraft relying on radar. The same would hold for any easy counter to other sensors. But, NATO can not *count* on such methods unless it becomes sure of the sensor and of the effectiveness of a deception technique, difficult criteria to satisfy. Just as with electronic countermeasures, NATO should seek to avoid depending on such techniques, use them when they are cheap, but not divert significant resources to them unless there seems no alternative.

MUNITIONS

A terminally guided submunition, searching out the target, would obviate the need for a highly accurate TBM. This is the technique to be used in NATO's follow-on forces attack (FOFA) concept. In that concept, the submunitions would seek out the Warsaw Pact tanks and other field forces of the "second echelon," forces usually well behind the front lines, but advancing to the battle. Since the forces attacked are moving, their precise location is impossible to predict, and some searching is needed. The approximate location is to be provided by deep surveillance assets, usually built by the United States, such as JSTARS, an airborne radar to detect moving vehicles far behind the front lines.

Such concepts may be available to the West in the 1990s. For the Soviets, despite Marshall N.V. Ogarkov's description of "automated reconnaissance-and-strike complexes," such concepts seem implausible before the year 2000. The Soviet strength is not in "smart" or "brilliant" submunitions, in technically elaborate sensors for surveillance, or in the quick, responsive command-and-control structures necessary to sort the flood of information and so to pick targets. Consequently, such submunitions should not be available to the Soviets for some time to come.

A single, large, explosive charge, called a unitary warhead, is the simplest munition. Such Soviet weapons have apparently been used by Iran in their current war. At the accuracies we are considering, such warheads are ineffective at most military tasks. Consequently, attention has focused on various submunitions packages, mostly patterned after western systems. These submunitions are not "smart," but simply spread the effect of the weapon over a larger area. For example, the U.S. Combined Effect Munition (CEM) is designed to destroy personnel and lightly armored vehicles when dropped by either aircraft or missiles. Alternatively, various western nations have built Kinetic Energy Penetrators (KEP) to crater concrete surfaces, primarily runways at airbases. These designs, from the French Durandal to the British JP-233, have been built to be dropped from aircraft, but the United

States examined versions deliverable via a modified Pershing missile. Presumably, such options are also open to the Soviet Union.

Other warhead possibilities have been suggested, notably chemicals and fuel-air explosives (FAE), but seem less of a problem for NATO than submunition packages. Chemical weapons are inherently an area weapon, with the payload of a TBM able to contaminate an area to radii larger than the accuracy of the old missiles. Thus, the possibility of chemical warheads is not a new problem created by the improvement in accuracy, but a problem NATO has faced for years, both from TBMs and aircraft. Chemically-armed TBMs only offer their quick flight time, which stresses the speed with which a defender must "button up," or adopt a posture resistant to chemical agents. Obviously, quick dissemination of whatever warning NATO receives is essential. Since even one such TBM reaching an unprepared base would kill many, these measures are always useful. Moreover, a quick defensive response to a chemical attack will be needed throughout a war, just to avoid offering too tempting a target for such attacks, however delivered. NATO must rely on that defense, together with the threat of retaliation, to counter chemical attacks independent of TBMs.

Fuel-air explosives would provide an area weapon, just as would a collection of CEMs, but with a different damage mechanism--overpressure. Unfortunately for the TBM, the problem of effectively dispersing a fuel from a TBM seems daunting. The comparative simplicity of CEM-style submunitions, coupled with their performance, makes them the more likely weapon.

All of these munitions suffer from the same problem, the severe weight constraint on a TBM. Even coupled with this improved accuracy, such weapons could not efficiently destroy most targets of interest. Rather, they must disrupt an important operation, or freeze the position of a target. Actual destruction of any target in NATO's rear must rely on aircraft to deliver the necessary combination of accuracy and weight. If aircraft are not available, or are unable to penetrate NATO's air defense, the disruption caused by TBMs is unlikely to be decisive.

TARGETS

But what targets are appropriate for these new conventional missiles? As we have seen, the TBMs are expensive. In comparison with the western missiles in the table, western aircraft cost roughly $30 million and carry 2 to 4 tonnes of munitions. For reasonable attrition of aircraft, say less than 10 percent per sortie, which is high by historical standards, aircraft would be much preferred if the goal of attack were simply to deliver tonnage cost effectively. Moreover, Soviet aircraft will be able to deliver precision munitions guided by the pilot or weapons officer in the future. Such weapons greatly increase the effectiveness of each bomb dropped, as the U.S. attack on Libya demonstrated. And, such accuracy is unlikely to be available on TBMs. Consequently, aircraft would be the preferred means of precision attack as well. Thus, TBMs will be an important new threat only to those NATO targets whose vulnerability stems from, or can be significantly increased by, the swiftness of the attack. Otherwise, Soviet aircraft could do the job.

Few targets satisfy these conditions. For example, while the Soviets may well wish to disrupt the dispersal of prepositioned supplies from POMCUS (prepositioning of materiel configured to unit sets) sites, such sites can hardly be emptied quickly; they are equally vulnerable to air attack and missile attack, but air can deliver a heavier blow. Choke points in lines of communications, such as bridges, likewise are targets for the time they are used, which is typically hours for large formations, not minutes. Consequently, even if small amounts of munitions could disrupt these targets, aircraft or cruise missiles could equally well deliver them. Similarly, nuclear weapons and their launchers can only have their dispersal from storage sites or kaserns delayed by TBMs, they cannot efficiently be destroyed. It requires a peculiar scenario to have nuclear weapons undispersed, but so poised to leave that the hour gained by TBMs over aircraft is critical.

Such targets as these may also be vulnerable to small quantities of munitions or chemicals, and so may need hardening, redundancy, or other measures urgently. For the issue of defense against TBMs though, they are largely irrelevant. TBMs are only one method of attack, so a defense "tuned" to them alone would fail to solve the problem. Conversely, any measure mitigating the non-TBM attacks should also handle TBMs.

Time-critical targets do exist, most obviously command-and-control centers, air defense sites, and airfields. Quick, assured disruption of any of these targets might well have an effect out of proportion to the weight of munitions expended, and thus would meet the criteria spelled out above. We will discuss each in turn to understand the potential of passive measures.

PASSIVE MEASURES FOR THE TIME-CRITICAL TARGETS

Attacks on command-and-control centers may offer the most direct payoff to the Soviets. If key NATO commanders could be isolated from the battle before it starts, dramatic advances into the Federal Republic of Germany could result. This is the one obvious case where the disruption of TBMs, even without a following aircraft attack, might affect the war. Actual effects would likely be less, since lower-level commanders would not remain paralyzed, but NATO must still avoid this possibility. Fortunately, passive means--mobility, redundancy, and hardening--could substantially mitigate this problem.

Mobile command-and-control centers present the Soviets with a formidable search problem. Assuming the Warsaw Pact intercepts, decodes, and correctly identifies NATO radio traffic, they will still have located only the transmitters, not the headquarters itself. Further searching, perhaps using satellites, would be needed to find the actual headquarters before it could be attacked. Denying the Soviets communication intelligence in the first place, further separating the transmitters from the center, adding transmitters to confuse the Warsaw Pact (and to mitigate their vulnerability), and hiding the center itself would substantially increase the survivability of these centers. For the Soviets to locate headquarters units before they move again should be difficult. Additionally, all of these measures also help the mobile command centers avoid attacks from aircraft, a threat that always exists, and indeed, may be more severe since aircraft can be equipped with on-board sensors for target detection.

Mobile command centers, or other mobile systems, could be located by human agents. The agents would presumably communicate the location to Warsaw Pact forces, which could attack the target with TBMs. However, the better attack option would usually again be aircraft, for then the center could be damaged and not just harassed. At the start of the war, TBMs or the agents themselves could attack the center. Such an attack would be particularly effective then, when disruption is most valuable. The mobility of these centers protects most of them from small numbers of agents, whether they would be attacked by TBMs or the agents, while they will always be vulnerable to direct attack from large numbers of agents. For that problem, the only response must be effective security in NATO's rear, which should be needed in any event.

Unfortunately, not all of NATO's command-and-control centers will be mobile. While the location of any fixed site will be known by the Soviets long before any war, the location of their communication antennas can be made variable. Here, redundancy, particularly hardened links from bunkers to transmitters placed well beyond the accuracy of these missiles, would be wise. The bunkers themselves must be hardened to withstand attacks by TBM warheads. (Obviously, security against agents is needed here too, but not in relation to TBMs.) These steps seem well within NATO's capacity, and again, offer resistance to attack from aircraft.

Air defense sites, such as the Hawk and Patriot surface-to-air missile (SAM) batteries, are an attractive target. While such sites are mobile, they remain fixed during operation and radiate their position with their radars. Consequently, and unlike quiet targets, they might be more easily located. Moreover, if they could be temporarily suppressed, many more Warsaw Pact aircraft might penetrate to NATO's rear. These targets thus also meet the criteria for TBM attack.

Again, though, passive options can help. The fire unit can be hardened to resist several attacks. Against CEM-style munitions, the vehicles can be armored, if only with Kevlar sheets. To foil chemical attack, the crews can be provided suits and warning. The fire unit can hide, with its radar largely quiet before an attack. Even decoy radars and mobility help, because TBMs need target location comparable to their accuracy. Finally, the number and range of these SAMs, particularly Patriot, provides some measure of redundancy to NATO's air defense.

Although passive defenses can help, it is here that an active defense seems most useful in the near term. Because the Patriot system can be upgraded to give it some anti-TBM capability, this could be done relatively inexpensively: the upgraded system would be based on the existing system and on its infrastructure. However, this active defense option should be considered as a potential addition to the passive defense options discussed above, not as a substitute. And, its effectiveness would be enhanced by the passive options.

In addition to SAMs, NATO also deploys fighter aircraft for air defense. As a general proposition, NATO's fixed-wing air capability--both for air defense and ground attack--help NATO offset the Warsaw Pact's ground force advantage. For this reason, neutralization of NATO's air capability is likely to be an early, high-priority objective of Pact forces. Thus, the vulnerability of NATO's air bases is a continuing area of concern.

Generally, airbases have one grievous vulnerability: a single runway necessary for operation and vulnerable to attack. An attack by less than a dozen of these conventional TBMs could crater that runway, trapping the aircraft. The available number of longer-range TBM launchers could thus threaten roughly 40 NATO airfields in a single salvo, and so attack all the bases for NATO's air defense fighter aircraft. Such an attack would remove defensive interceptors from the skies, allowing a follow-up air attack to destroy valuable aircraft on the ground.

Several passive counters could dramatically reduce this vulnerability. The most basic is to multiply the number of aimpoints the TBMs must attack. Space exists at many airbases sufficient to build alternate landing and recovery strips. This was the most common passive measure considered in the past, but its utility is greatly increased if it is combined with other ideas.

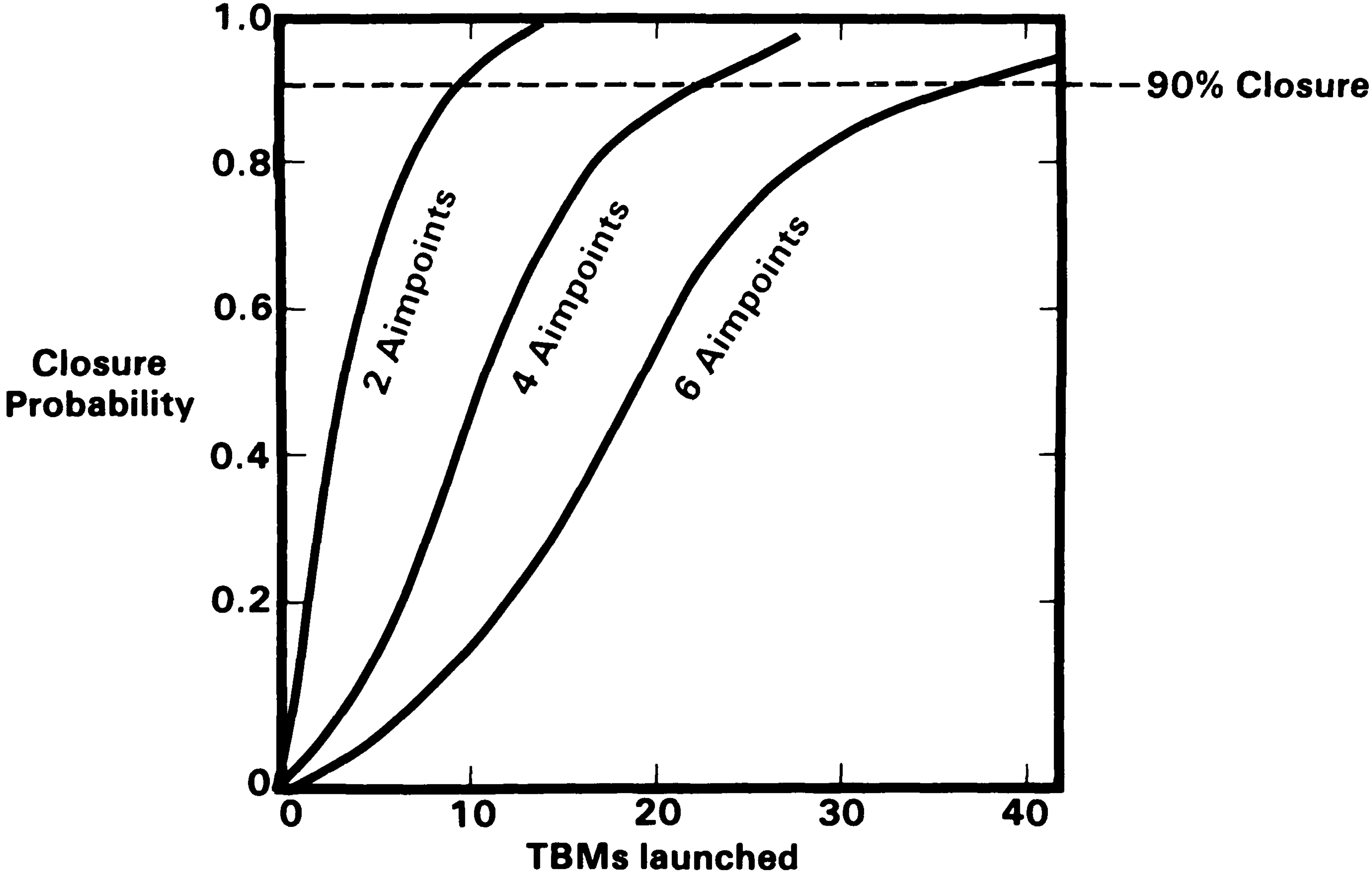
Newer aircraft can and are being designed to require much shorter takeoff distances. Aircraft can also be designed to use ski-jump style ramps to aid in short takeoffs. Without a ramp, a minimum takeoff distance of 900 feet is projected for the F-15E. In contrast, most of the early calculations for cratering attacks assumed minimum operating surfaces about 3500 feet long. Simultaneously, NATO is acquiring mobile aircraft arresting systems to shorten the needed landing distance. Other such changes, such as "jump struts," could further this trend without requiring radical redesign of NATO's aircraft.

Additionally, plans can be made to disperse interceptor aircraft to other airbases on strategic warning so that more bases must be attacked to pin down NATO's air defense aircraft. These airbases could even be far in NATO's rear, in England, France, or even Spain, where only the few SS-12's could attack them, although with some penalty in capability. Some aircraft might even operate from preselected lengths of autobahn or outlying runways, relying on an existing base for most logistical support.

Together, these changes can significantly increase the number of aimpoints that the TBM attack must hit. The increase in the number of TBMs required to close a single airbase is shown in Figure 1. The leftmost curve is for an airbase which initially only requires two areas of destruction, or aimpoints, to leave no length of runway long enough to use. After the aircraft changes outlined above, each possible takeoff surface on an airbase should require at least five aimpoints for this attack, and perhaps more, depending on how many measures are implemented. Additionally, each base should have at least two usable surfaces which must be so attacked, even if it supports no outlying strips or lengths of autobahn. The additional multiplication of aimpoints available through dispersal to other airbases further dilutes the attack. Thus, the number of aimpoints quickly outstrips the projected number of Soviet TBMs, and does so relatively cheaply.

Complementing this approach are rapid repair techniques. While such repairs cannot in themselves allow an airbase closed by TBMs to open before a follow-up aircraft attack arrives, they do allow the airbase to recover much more quickly thereafter. Thus, to keep its advantage, the Warsaw Pact must either allocate still another salvo of TBMs to keep the base closed, or use aircraft to attack the runways rather than the valuable aircraft on the ground. Such rapid repair requires an advanced means of surveying an airbase after an attack to find the key damage, new repair techniques such as precast slabs or quick setting cement, and airbase personnel trained to react quickly.

Fig. 1 -- VALUE OF MULTIPLE AIMPOINTS



Other potential Soviet TBM attacks on the operating surfaces must also be considered. Small mines, designed to detonate at the approach of an aircraft or an explosive ordnance disposal unit, would certainly block operations for a time. If they were used on runways, the counters for a cratering attack would also counter them. More seriously, the mines might be deployed at "choke-points" in the airbase ramp structure. To deal with this attack, whether delivered by TBMs or aircraft, the U.S. Air Force is considering two sets of options. One is again multiplication of aimpoints. In this case, new taxiways are needed to avoid depending on a single path to the runway along with widening of intersections to require more TBMs per aimpoint. The other option is rapid clearing. Again, this requires speedy damage assessment, perhaps airborne, to determine whether mines need to be cleared and, if so, the most important ones to clear. It also requires a vehicle capable of clearing such mines and surviving. This is essentially an armored bulldozer, called ORACLE.

Airbases in general are subject to a wide range of attacks, from TBMs through aircraft to human agents. A wide range of active and passive measures might counter these attacks. Some measures, such as rapid repair, are not limited to countering one attack, while others, such as ground security against sabotage, more obviously are. Clearly, given the wide range of both attacks and passive options, cost-effectiveness analysis is needed to help set priorities.

Nonetheless, airbases remain large concentrations of valuable, interdependent weaponry and can be reached by TBMs. In particular, for NATO aircraft to attack the Warsaw Pact rear, large groups of aircraft from several bases must be coordinated into "strike packages." In any such large-scale, tightly timed activity, the effect of disruption on a single base is multiplied. If passive measures such as described above are insufficient to allow this level of coordination to continue under sporadic TBM attacks, it could be worthwhile to extend the improvements of SAMs mentioned above to provide a thin defense of airbases. The defense could be thin, as it need not counter large attacks, but rather only intercept a few TBMs, arriving perhaps every half hour. The defense need not be highly effective either, because single TBMs would do little damage by themselves.

SUMMARY

Moderate numbers of tactical ballistic missiles (TBMs) armed with conventional munitions can largely be countered by passive means. Such TBMs with the posited accuracies do not threaten significant destruction, but only disruption and delay. Whether by mobility, hardening, dispersal of operations, redundancy, or rapid repair, this disruption can be reduced to small levels. In this case, the weakness of these TBMs seems indeed to outweigh their strengths.

In this view, active defense becomes only one of many options available to NATO to improve its conventional defense. Of course, active defense would have an unquantifiable psychological plus--it is always better to block an attack than to clean up afterwards. But NATO has many high-priority needs, including air defense, but also including such things as anti-armor weaponry and supplies of basic munitions. Fortunately, the promise of passive defenses should buy time for NATO to weigh the role of active defense against TBMs.